OPTICAL DISK CONTROLLER AND
OPTICAL DISK DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to an optical disk controller that performs processing such as modulation on a signal obtained from a pickup by reading data recorded on an optical disk.

In recent years, development of optical disk devices for DVD-ROMs, DVD-RAMs, in succession to those for CD-ROMs, has made progress. Many of such optical disk devices are implemented by the combination of an optical disk controller that performs a series of data processing including modulation, error correction, buffering, and transfer to host and a system controller that controls components of the optical disk device such as a pickup and a servo.

Figure **10** shows an optical disk device including a conventional optical disk controller. Referring to Figure **10**, the optical disk device includes: a spindle motor **101** for rotating an optical disk **100**; a pickup **102** for reading data from the optical disk **100** by radiating the optical disk **100** with laser light; a servo **103** for positioning the pickup **102**; an optical disk controller (ODC) **710** for performing signal processing; and a system controller **720** for controlling the operation of the entire system.

The optical disk controller **710** includes a command interpreter **711**, a demodulator **712**, an error correction section **713**, a data buffer **714**, a host interface **715**, and a status generator **716**.

A host PC **730** sends a command to the optical disk device requesting data read from the optical disk **100**. On receipt of the data read command via the host interface **715**, the system controller **720** controls the spindle motor **101** to rotate the optical disk **100** and the servo **103** to move the pickup **102** to a target sector. The system controller **720** then issues command READ to the optical disk controller **710**.

On receipt of the command READ, the command interpreter **711** instructs the demodulator **712** to read specified sectors. The demodulator **712** monitors data read by the pickup **702** and, when recognizing data of a head sector, sends the data of the sector to the error correction section **713**. The error correction section **713** executes error correction for the data output from the demodulator **712**. The error-corrected data is then temporarily stored in the data buffer **714**.

The status generator **716** generates a status report or "status" for the data based on the error correction results received from the error correction section **713**. Figure 11 shows examples of generated status reports, each of which is composed of items of information category, factor, and auxil-

iary information. The information category indicates whether the issued command was "continued", "normally ended", or "abnormally ended". The factor indicates the state of the current sector. If any problem arises, information on the problem is added to this item. The auxiliary information includes the current sector ID and the buffer page number on which the error-corrected data has been stored.

The status generator **716** generates a status report every time data of each sector is read, and outputs the results to the system controller **720**. The factor of the status report is "normal" for the sector of which data has been normally corrected. For the sector of which data has failed to be normally read during reading of the sector, the factor of the status report includes relevant information, so that the system controller **720** is notified of the information.

Thus, the optical disk controller **710** generates the status report representative of the inner state thereof every error correction, thereby enabling the system controller **720** to keep track of the operation of the optical disk controller **710**. Based on the status report received, the system controller **720** can determine whether read operation be continued or aborted. In this way, proper read processing is realized.

In optical disk devices, one of factors for determining drive performance is the rotational speed of the disk. As

the rotational speed of the disk is higher, the data read/write time is shorter and the data processing size per unit time is greater. Therefore, nowadays, operation at a higher rotational speed is requested for optical disk devices.

In the conventional status report output procedure, as the rotational speed of the disk is higher, the period of status report output becomes shorter. This reduces the time allowance given for determining whether the processing be continued or aborted based on a received status report after the status report is received. Consequently, as the rotational speed of the disk increases, the burden of the system controller becomes excessively large.

SUMMARY OF THE INVENTION

An object of the present invention is providing an optical disk controller that reduces the frequency of output of status reports to relieve the burden of a system controller.

Concretely, the optical disk controller for performing signal processing for an optical disk according to the present invention includes: a status generator for generating status reports each representing the operation state of the optical disk controller; and a status sampling section for sampling the status reports.

According to the invention, the status reports generated

by the status generator are sampled by the status sampling section. By this sampling, the frequency of output of status reports becomes lower than the frequency of generation of status reports, resulting in relieving the burden of a system controller that performs processing for the respective status reports.

Preferably, the status sampling section includes a sampling interval setting portion for setting a status sampling interval.

Preferably, also, the sampling interval setting portion sets the sampling interval according to the rotational speed of the optical disk. By this setting of the sampling interval according to the rotational speed of the optical disk, the burden of the system controller that performs processing for the respective status reports is avoided from increasing even when the rotational speed of the optical disk is enhanced. Preferably, the sampling interval setting portion determines the rotational speed of the optical disk according to a synchronization period of a signal demodulated from the optical disk.

The optical disk controller may further includes assigning means for allowing the sampling interval setting portion to set the sampling interval according to a command input externally.

Preferably, the sampling interval setting portion sets

the sampling interval according to an error rate of a signal demodulated from the optical disk.

The status sampling section preferably includes a sampling category storing portion that stores "sampling abort" status indicating that sampling operation should be aborted, and, when the status report generated by the status generator matches with the "sampling abort" status stored in the sampling category storing portion, the sampling is aborted.

The status sampling section preferably includes a sampling category storing portion that stores "forced sampling" status indicating that the status report should be output even during sampling operation, and, when the status report generated by the status generator matches with the "forced sampling" status stored in the sampling category storing portion, the status report is output even during sampling operation.

The optical disk controller may further include assigning means for setting sampling category information representing the relationship between a factor in the status report and sampling operation and storing the sampling category information in the sampling category storing portion. The status sampling section may update the sampling category information stored in the sampling category storing portion according to a signal demodulated from the optical disk.

It is also an object of the present invention to provide

an optical disk device that includes the optical disk controller according to the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a view showing the construction of an optical disk device including an optical disk controller of the present invention.

Figure 2 shows commands acceptable by the optical disk controller in Figure 1.

Figure 3 shows examples of status reports generated by the optical disk controller in Figure 1.

Figure 4 shows a flowchart of the operation of a sampling interval setting portion shown in Figure 1.

Figures 5 and 6 show a flowchart of the operation of a sampling determination portion shown in Figure 1.

Figure 7 shows an example of sector arrangement of an optical disk.

Figure 8 shows an example of sampling category information stored in a sampling category storing portion shown in Figure 1.

Figure 9 shows an example of status report sampling results according to the present invention.

Figure 10 is a view showing the construction of an optical disk device including a conventional optical disk controller.

Figure 11 shows an example of conventional status report output results.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be described with reference to the accompanying drawings.

Figure 1 illustrates an optical disk device 1 including an optical disk controller of an embodiment according to the present invention. Referring to Figure 1, the optical disk device 1 includes a spindle motor **101** for rotating an optical disk **100**; a pickup **102** for reading data written on the optical disk **100**; and a servo **103** for positioning the pickup **102**. An optical disk controller (ODC) **200** performs signal processing for the optical disk **100**. A system controller **300** controls the entire optical disk device. A host PC or AV decoder **2** sends a command to the optical disk device 1 and receives data from the optical disk device 1.

The internal construction of the optical disk controller **200** will be described. The optical disk controller **200** may be implemented as LSI, for example.

A demodulator **201** demodulates a signal read from the optical disk **100**. An error correction section **202** corrects error data included in the data demodulated by the demodulator **201**. The error-corrected data is temporarily

stored in a data buffer **203**. The data stored in the data buffer **203** is output to the host PC or AV decoder **2** via a host interface **204**. The demodulator **201**, the error correction section **202**, and the host interface **204** are implemented by hardware, for example. The data buffer **203** is implemented by DRAM, for example.

A status generator **210** generates a code, i.e., a status report, indicating the operation state of the optical disk controller **200**. A status sampling section **220** samples status reports generated by the status generator **210** and outputs sampled status reports to the system controller **300**. A command interpreter **230** as an assigning means interprets commands sent from the system controller **300** and controls activation of the demodulator **201** and the like, for example. The status generator **210**, the status sampling section **220**, and the command interpreter **230** are implemented by a combination of a microcomputer and a program, for example.

The status sampling section **220** includes a sampling interval setting portion **221**, a sampling determination portion **222**, and a sampling category storing portion **223**. The sampling interval setting portion **221** sets the sampling interval of status reports and holds the set sampling interval. In this embodiment, the rotational speed of the optical disk **100** is obtained from the synchronization period of the signal demodulated by the demodulator **201**, and the sampling

interval is set according to the obtained rotational speed. The sampling category storing portion **223** stores, as sampling category information, categories for "sampling abort" status indicating that the sampling should be aborted, "forced sampling" status indicating that the status report should be forcibly sampled even when it is otherwise to be omitted, and the like. The sampling determination portion **222** determines whether or not a given status report should be sampled based on the sampling interval held in the sampling interval setting portion **221** and the sampling category information stored in the sampling category storing portion **223**.

Figure **2** shows commands acceptable by the command interpreter **230** of the optical disk controller **200**. It is assumed in this embodiment that commands READ (read a sector), TRANSFER TO HOST (data transfer to host PC or AV decoder), SAMPLING DESIGNATION (sampling start/end), SAMPLING STATUS DESIGNATION (setting of sampling category information), and ODC OPERATION MODE are acceptable.

Figures **3(a)** and **3(b)** show examples of status reports generated by the status generator **210**: Figure **3(a)** shows status reports for video/audio reproduction, concretely, for DVD players and CD players, for example, and Figure **3(b)** for data read/write, concretely, for DVD-ROM drives and CD-ROM drives, for example. As shown in Figures **3(a)** and **3(b)**, the information category includes "continued", "aborted due to

error", and "normally ended". The factor includes "normal", "data category changed", "sector discontinued", "error rate increased", "correction not permitted", "buffer full", and the like. The auxiliary information includes the sector ID to be read, the buffer page number, and the like.

The factor "correction not permitted" corresponds to the category "continued" for video/audio reproduction while it corresponds to the category "aborted due to error" for data read/write. This is because, for video/audio application, reproduction should preferably be continued without interruption even if a signal includes some noise. On the contrary, for data application, data including an error is of no use.

It is also assumed in this embodiment that the status report is output every sector and that error correction is made every sector.

Figure **4** is a flowchart showing the operation of the sampling interval setting portion **221**. The processing at each step shown in Figure **4** is as follows.

Step **S01**: Obtain the rotational speed of the disk (expressed by double speed) according to the synchronization period of a demodulated signal output from the demodulator **201**.

Step **S02**: Proceed to step **S03** if the rotational speed is quadruple or lower, or otherwise proceed to step **S04**.

Step **S03**: Set the sampling interval at "4" (that is, one every four status reports is output; this is also applicable

to the subsequent values of sampling interval) and terminate the operation.

Step **S04**: Proceed to step **S05** if the rotational speed is octuple or lower, or otherwise proceed to step **S06**.

Step **S05**: Set the sampling interval at "8" and terminate the operation.

Step **S06**: Proceed to step **S07** if the rotational speed is 16 times or lower, or otherwise proceed to step **S08**.

Step **S07**: Set the sampling interval at "16" and terminate the operation.

Step **S08**: Set the sampling interval at "20" and terminate the operation.

Figures **5** and **6** are a flowchart showing the operation of the sampling determination portion **222**. The processing at each step shown in Figure **5** is as follows.

Step **S11**: Obtain sampling category information from the sampling category storing portion **223**.

Step **S12**: Determine whether or not the status report generated by the status generator **210** corresponds to "sampling abort" status. If yes, proceed to step **S13**. Otherwise, proceed to step **S14**.

Step **S13**: Set a sampling execution flag FLG at "0" and proceed to step **S21** (Figure **6**).

Step **S14**: Determine whether or not the status report generated by the status generator **210** corresponds to "forced sam-

pling" status. If yes, proceed to step **S15**. Otherwise, proceed to step **S21**.

Step **S15**: Set a sampling counter CT at "0" and proceed to step **S21**.

The processing at each step shown in Figure **6** is as follows.

Step **S21**: Determine whether or not the sampling execution flag FLG is "0". If "0", proceed to step **S22** for aborting the status sampling. If not, proceed to step **S23** for executing status sampling.

Step **S22**: Output the status report generated by the status generator **210** to the system controller **300** and terminate the operation.

Step **S23**: Determine whether or not the sampling counter CT is "0". If "0", proceed to step **S24** since the current status report generated by the status generator **210** should be output. If not, proceed to step **S25** since the current status report should be omitted.

Step **S24**: Output the current status report generated by the status generator **210** to the system controller **300**.

Step **S25**: Increment the value of the sampling counter CT by "1".

Step **S26**: Compare the value of the sampling counter CT with the sampling interval received from the sampling interval setting portion **221**. If these values match with each other,

proceed to step **S27**. If not, that is, if the value of the sampling counter CT has not reached the sampling interval, terminate the operation.

Step **S27**: Set the sampling counter CT at "0".

Hereinafter, the operation of the optical disk controller of this embodiment with the above construction will be described in a concrete manner. Assume herein that the optical disk **100** has a sector arrangement as shown in Figure **7**. That is, as is seen from Figure **7**, the data category has changed in sector 752 and sector discontinuation has occurred in sector 756.

The host PC or AV decoder **2** sends a command to the optical disk device **1** requesting to read data from the optical disk **100**. The command is received by the system controller **300** via the host interface **204**.

The system controller **300** issues command SAMPLING VALID to the command interpreter **230**. The system controller **300** also issues command STATUS CONDITIONS to the command interpreter **230**, in which "sampling abort" is set for a status report having the factor "sector discontinued", and "sampling target" is set for a status report having the factor "correction not permitted" or "error rate increased". The system controller **300** further issues command ODC OPERATION MODE: FOR VIDEO/AUDIO REPRODUCTION to the command interpreter **230**.

The system controller **300** then instructs the spindle mo-

tor **101** to rotate the optical disk **100** and the servo **103** to move the pickup **102** to a target sector.

On receipt of the command SAMPLING VALID, the command interpreter **230** sets the sampling execution flag FLG of the sampling determination portion **222** of the status sampling section **220** at "1". A signal read by the pickup **102** is sent to the demodulator **201**, which measures the period of one sector and determines the rotational speed as octuple. On receipt of the information from the demodulator **201** that the rotational speed of the disk **100** is octuple, the sampling interval setting portion **221** sets the sampling interval at "8".

On receipt of the command STATUS CONDITIONS, the command interpreter **230** sets sampling category information and stores the results in the sampling category storing portion **223**. Stored in the sampling category storing portion **223** is sampling category information as shown in Figure **8** in this embodiment, which represents the relationship between the factor in the status report and the corresponding sampling operation. Concretely, "sampling abort" is designated for the factor "sector discontinued", "sampling target" is designated for the factors "error rate increased" and "correction not permitted", and "forced sampling" is designated for the factor "data category changed". For the other factors, "sampling target" is designated.

The system controller **300** issues command READ: SECTOR TO

BE READ (750), BUFFER PAGE (10) to the command interpreter **230**.

On receipt of the command READ, the command interpreter **230** instructs the demodulator **201** to start reading data from sector 750. The demodulator **201** monitors data sent from the pickup **102** and, when recognizing sector 750, sends data of this sector to the error correction section **202**.

The error correction section **202** executes error correction for the data output from the demodulator **201**, and outputs the error correction results to the status generator **210**. Recognizing that sector 750 has been normally error-corrected, the status generator **210** generates the status report "continued / normal / sector: 750" for sector 750.

On receipt of the status report for sector 750, "continued / normal / sector: 750", generated by the status generator **210**, the sampling determination portion **222** operates according to the flowchart shown in Figures **5** and **6**.

First, the sampling determination portion **222** retrieves the sampling category information representing the relationship between the factor in the status report and the corresponding sampling operation, from the sampling category storing portion **223** (step **S11**). Since the status "continued / normal / sector: 750" is not "sampling abort" status, that is, does not have the factor "sector discontinued" (step **S12**), the process proceeds to step **S14**. Since the status "contin-

ued/ normal / sector: 750" is "sampling target" status (step **S14**), the process proceeds to step **S21**.

At step **S21**, since the sampling execution flag FLG is "1" indicating that sampling is to be executed, the process proceeds to step **S23**. At step **S23**, since the sampling counter CT is "0" indicating that the status report is to be output, the status report "continued/ normal / sector: 750" is output to the system controller **300**. At step **S25**, the value of the sampling counter CT is incremented by "1". At step **S26**, the value of the sampling counter CT is compared with the sampling interval ("8" in this embodiment) received from the sampling interval setting portion **221**. Since the value of the sampling counter CT is "1", which is smaller than the sampling interval, the operation is terminated.

Next, sector 751 is read. On receipt of the status report for sector 751 "continued / normal / sector: 751" generated by the status generator **210**, the sampling determination portion **222** operates according to the flowchart shown in Figures **5** and **6**. The status "continued / normal / sector: 751" is determined as "sampling target" status, and the value of the sampling counter CT is "1". Therefore, sampling of this status report is omitted.

Sector 752 is then read. The error correction section **202** executes error correction for data output from the demodulator **201**, and outputs the error correction results to

the status generator **210**. Being informed of a change in data category by the data buffer **204**, the status generator **210** generates the status report "sector: 752 / data category changed" for sector 752.

On receipt of the status report for sector 752 "sector: 752 / data category changed" generated by the status generator **210**, the sampling determination portion **222** operates according to the flowchart shown in Figures **5** and **6**.

First, the sampling determination portion **222** retrieves the sampling category information representing the relationship between the factor in the status report and the corresponding designated sampling operation from the sampling category storing portion **223** (step **S11**). Since the status "sector: 752 / data category changed" is not "sampling abort" status, that is, does not have the factor "sector discontinued" (step **S12**), the process proceeds to step **S14**. Since the status "sector: 752 / data category changed" is "forced sampling" status, the value of the sampling counter CT is set at "0" at step **S15**.

At step **S21**, since the sampling execution flag FLG is "1" indicating that sampling is to be executed, the process proceeds to step **S23**. At step **S23**, since the sampling counter is "0" indicating that the status report is to be output, the status report "sector: 752 / data category changed" is output to the system controller **300**. At step **S25**,

the value of the sampling counter CT is incremented by "1". At step **S26**, the value of the sampling counter CT is compared with the sampling interval ("8" in this embodiment) received from the sampling interval setting portion **221**. Since the value of the sampling counter CT is "1", which is smaller than the sampling interval, the operation is terminated.

On receipt of the status "sector: 752 / data category changed" from the status sampling section **220**, the system controller **300** determines whether the read operation be continued or aborted. Assume in this case that the read operation is continued.

Next, sector 753 is read. The sampling determination portion **222** receives the status report for sector 753 "continued / normal / sector: 753" generated by the status generator **210**. This status is determined as "sampling target", and the value of the sampling counter CT is "1". Therefore, sampling of this status report is omitted. Subsequently, sector 754 is read. The sampling determination portion **222** receives the status report for sector 754 "continued / normal / sector: 754" generated by the status generator **210**. This status is determined as "sampling target", and the value of the sampling counter CT is "2". Therefore, sampling of this status is omitted.

Sector 755 is then attempted to be read but found missing. The demodulator **201** therefore determines as "sector

discontinued", and proceeds to read the next sector 756. The status generator **210** is informed of the "sector discontinued" by the demodulator **201**, and generates the status report "sector: 756 / sector discontinued" representing that sector 756 is "sector discontinued".

On receipt of the status "sector: 756 / sector discontinued" generated by the status generator **210**, the sampling determination portion **222** operates according to the flowchart shown in Figures **5** and **6**.

First, the sampling determination portion **222** retrieves the sampling category information representing the relationship between the factor in the status report and the corresponding designated sampling operation from the sampling category storing portion **223** (step **S11**). Since the status "sector: 756 / status discontinued" is "sampling abort" status, that is, has the factor "sector discontinued" (step **S12**), the process proceeds to step **S13**. At step **S13**, the sampling execution flag FLG is set at "0", and process proceeds to step **S21**.

At step **S21**, since the sampling execution flag FLG is "0", it is determined that the sampling is aborted. The status report "sector: 756 / status discontinued" is output to the system controller **300** (step **S22**), and the operation is terminated.

At the above point, the sampling execution flag FLG was

set at "0" indicating that the status sampling is aborted. Therefore, this status report "sector: 756 / status discontinued" and all the subsequent status reports are sent to the system controller **300** without sampling. That is, as for sectors 757 and 758 to be subsequently read, generated status reports are output without sampling.

Figure **9** shows the results of the above sampling. The system controller **300** has received only the status reports shown in Figure **9**. In other words, the status reports for sectors 751, 753, and 754 were omitted in the sampling. The status report for sector 752 which would have otherwise been omitted was output because it had the factor "data category changed". Also, since sector 755 was missing, the status report for sector 756 that had the factor "sector discontinued" was determined as "sampling abort" status. By this determination, all the status reports for sector 756 and the subsequent sectors were output.

Thus, as described above, the optical disk controller **200** executes sampling of status reports to be output to the system controller **300** while selectively outputting important information during the sampling. This reduces the data amount of status reports the system controller **300** must handle individually to provide determination. Therefore, the number of status reports is prevented from simply increasing when the rotational speed of the optical disk **100** is enhanced,

as in the conventional case. As a result, the burden of the system controller **300** is relieved.

In the above embodiment, the status report was generated on the premise that one error correction corresponds to one sector. The present invention is also applicable to other cases, for example, the case where one error correction corresponds to 16 sectors.

In the above embodiment, the sampling interval setting portion **221** set the sampling interval according to the synchronization period of a signal read from the optical disk **100**. The setting of the sampling interval may also be made in other ways. For example, the sampling interval may be set according to the error rate of a signal read from the optical disk **100**. Alternatively, the command interpreter **230** as an assigning means may specify the sampling interval according to a command supplied from the system controller **300**.

In the above embodiment, the command interpreter **230** as an assigning means set the sampling category information representing the relationship between the factor in the status report and the corresponding sampling operation according to a command from the system controller **300**, and stored it in the sampling category storing portion **223**. The sampling category information stored in the sampling category storing portion **223** may further be updated according to the synchronization period, the error rate and so forth of a signal de-

modulated from the optical disk **100**.

In place of the sampling category information representing the relationship between the factor in the status report and the sampling operation, the categories of "sampling abort" status and "forced sampling" status may be stored in the sampling category storing portion **223**.

While the present invention has been described in a preferred embodiment, it will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than that specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention that fall within the true spirit and scope of the invention.